Collaviz®

Scientific Visualization for Decision Support

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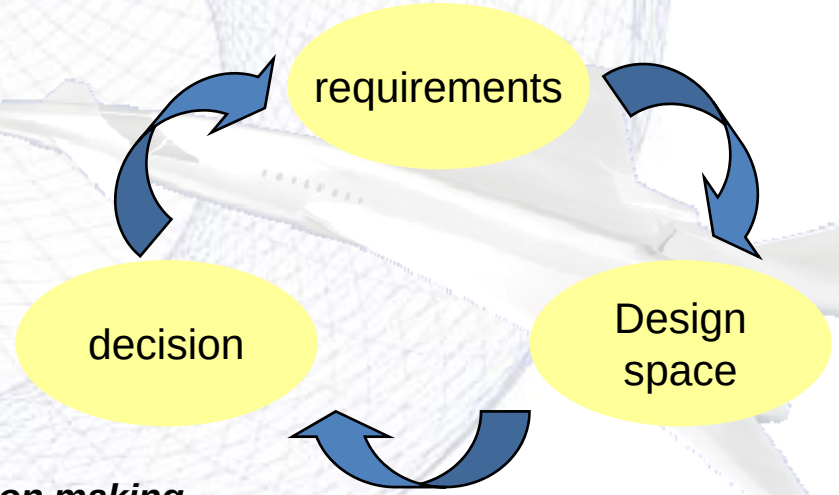
“Tell me and I'll forget;
show me and I may remember;
involve me and I'll understand.”
Chinese proverb

Scientific Visualization for Decision Support: **Industrial Vision**

Michel.Ravachol@dassault-aviation.com

Decision making loop in design

Evaluate requirements impact



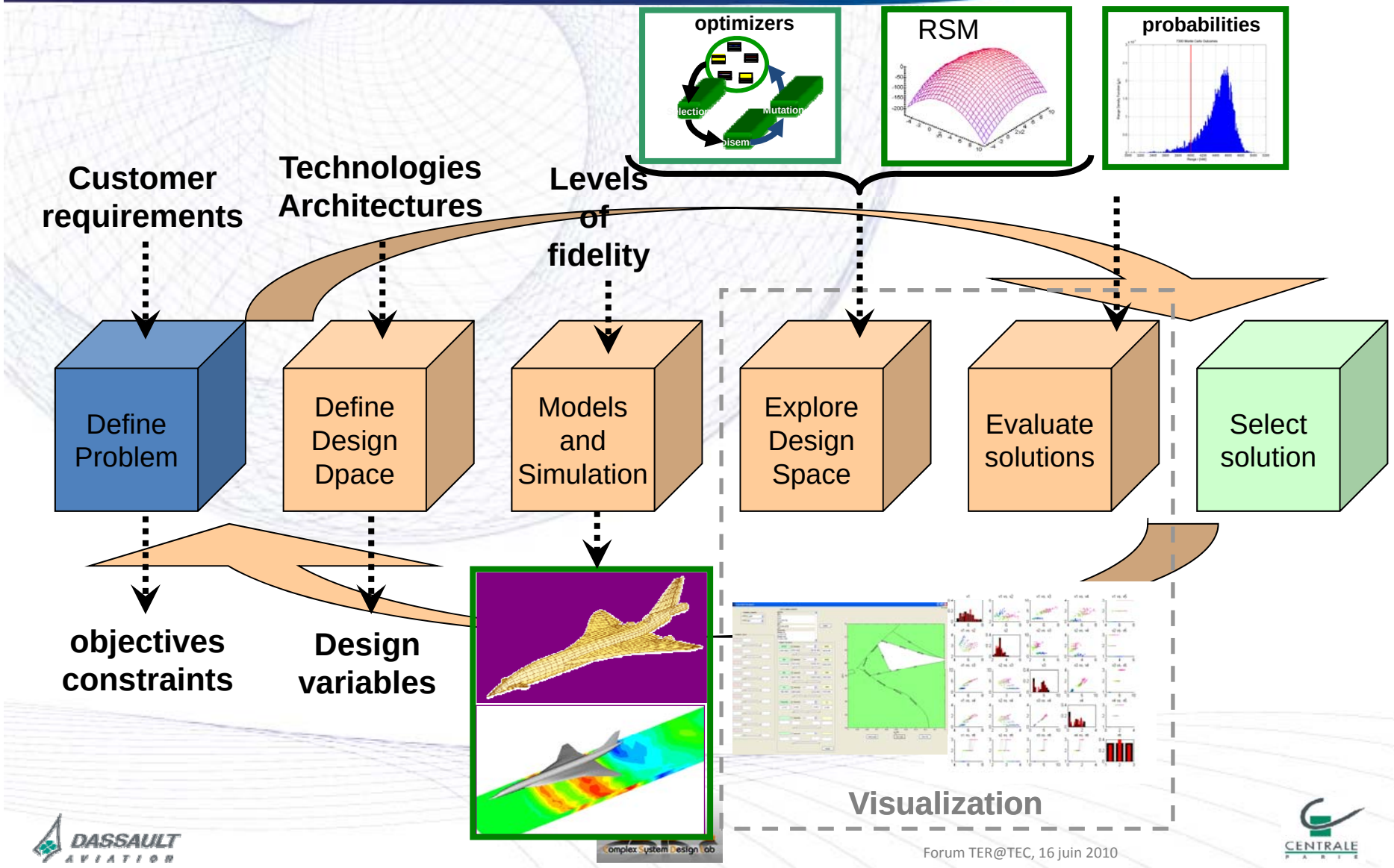
Synthesis to support decision making

- Synthesis of important parameters
  - What are the limits and where are they.
  - Impact of componant performances on global performances
- Propose trade offs
  - Between requirements
  - On design parameters
- Manage risks
  - Quantitative evaluation

Systematic and automatic exploration

- Understand the design space
  - What are the important parameters ?
  - How the requirements interact with each others?
  - Where are the most promising solutions ?
- Generate models dedicated to decision making
  - Trade offs
  - Evaluate risks

Design loop


optimizers
RSM
probabilities
Customer requirements
Technologies Architectures
Levels of fidelity
Define Problem
Define Design Dpace
Models and Simulation
Explore Design Space
Evaluate solutions
Select solution
objectives constraints
Design variables
Visualization

CSDL project

Technical challenges :

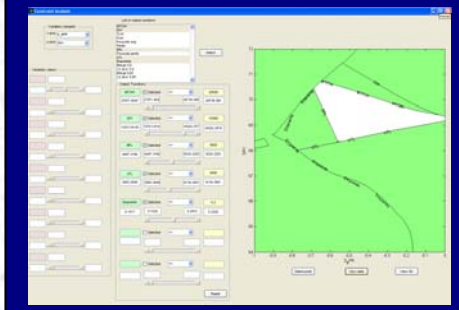
- Management of a hierarchy of interoperable surrogate models
- Evaluate the robustess of results wrt risks and uncertainties
- Exploration techniques adapted to the different level of fidelity of the models
- Methogology to analyze the design process of complex systems
- Develop interactive visualization tools to support decision making

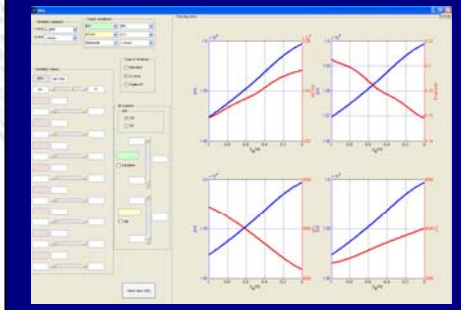
Inspiration :

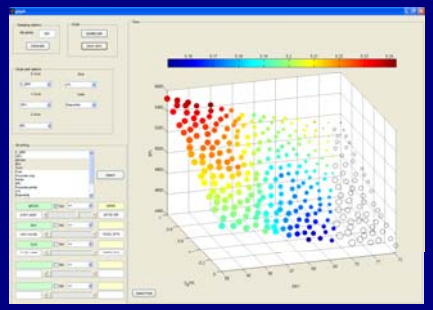
Georgia Tech *ASDL*
Collaborative Visualization Environnement

Goal : Interactive design reviews

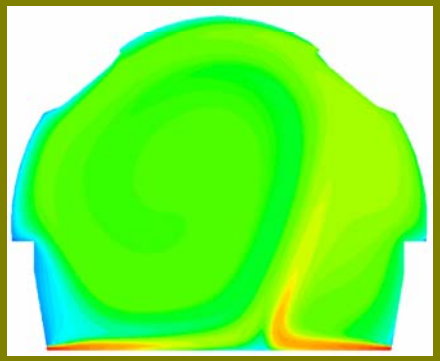
"Performance" view



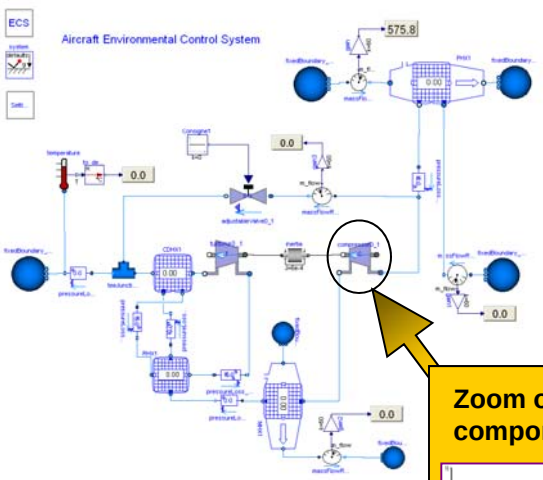




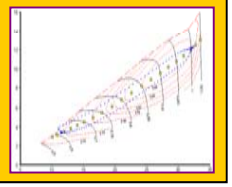
"Physical" view



"System" view



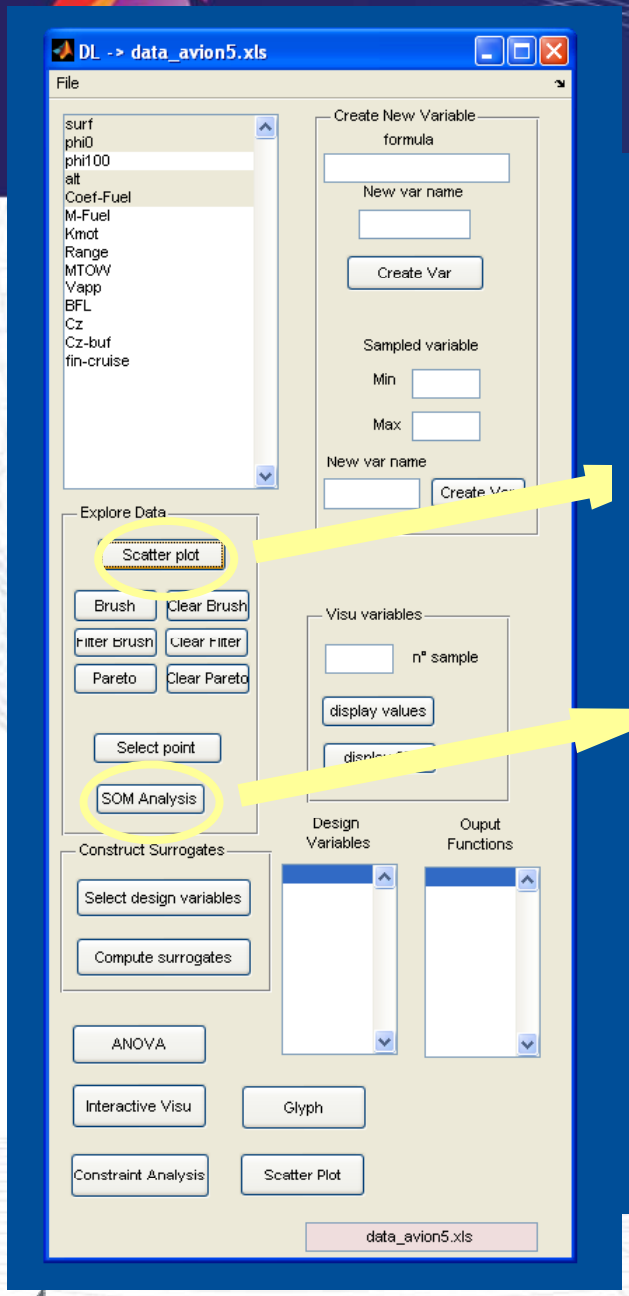
Zoom on one componant

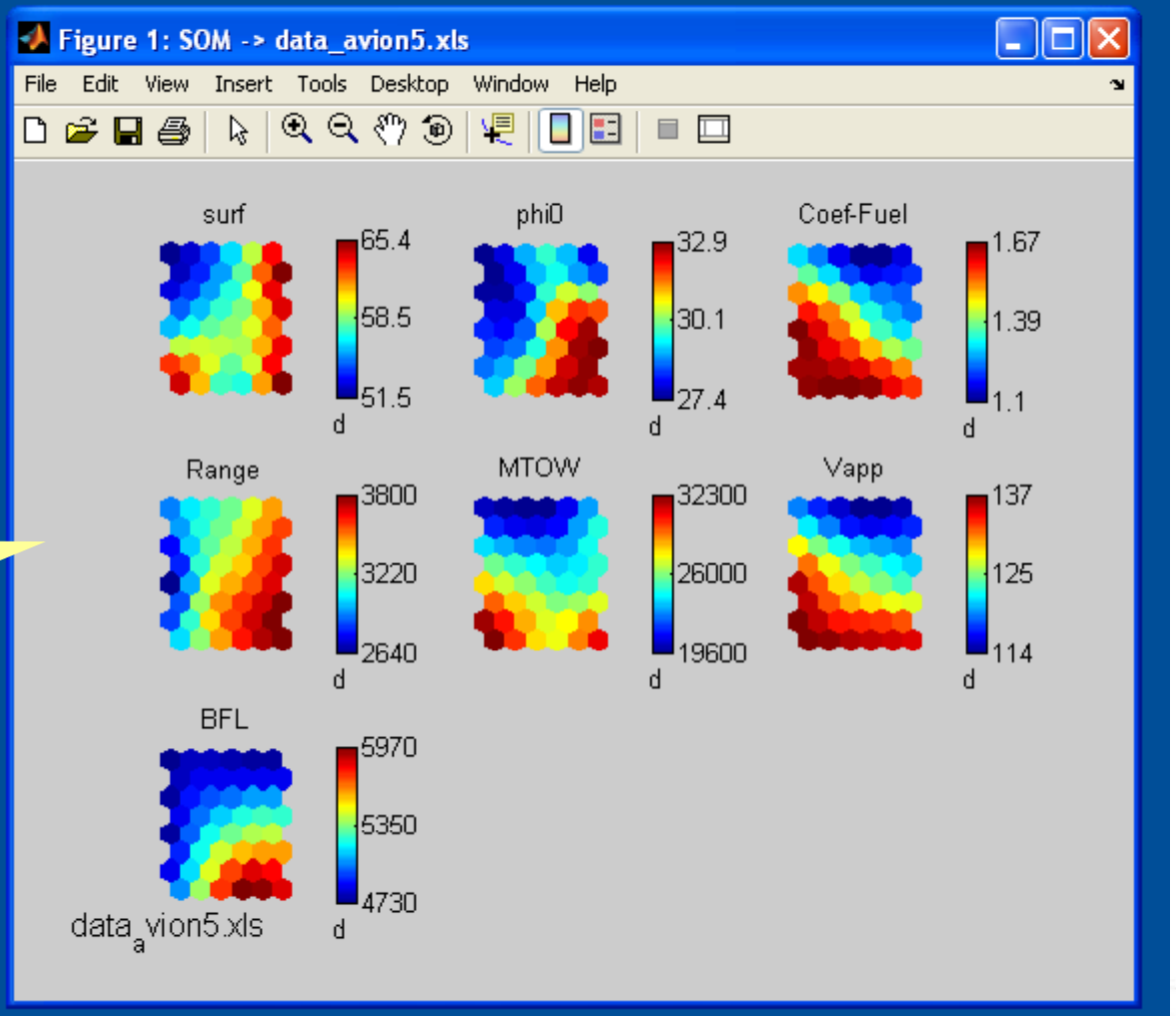


Interactive visualization of the impact of the design parameters on

- global performances
- physical solutions
- componant behavior

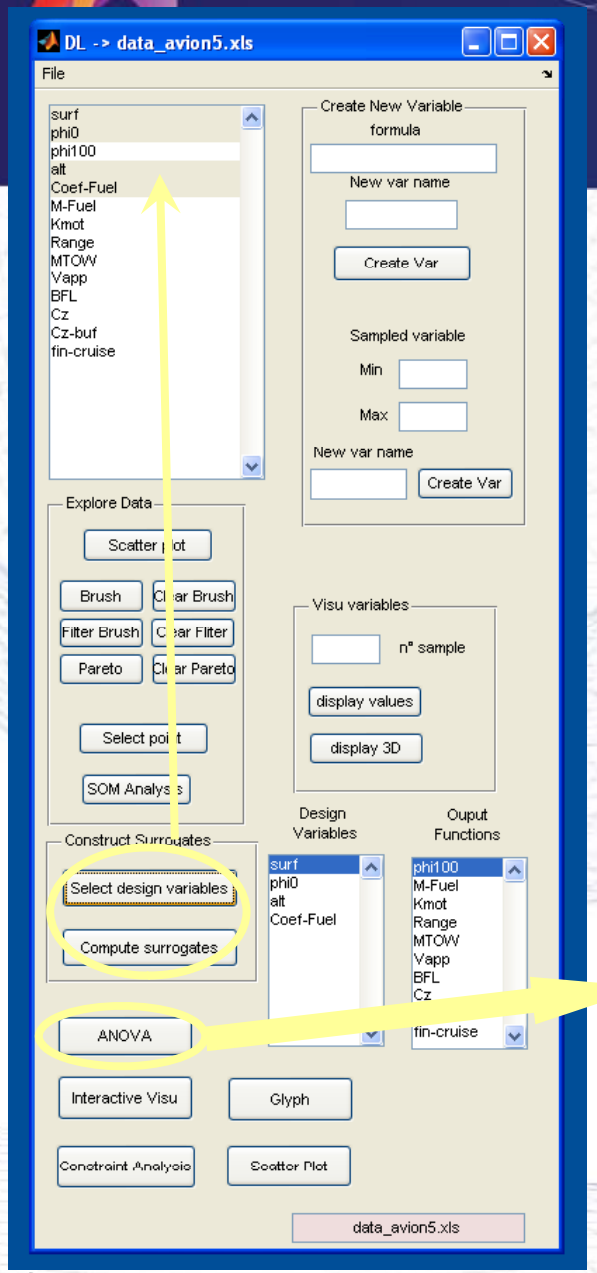
Initial step

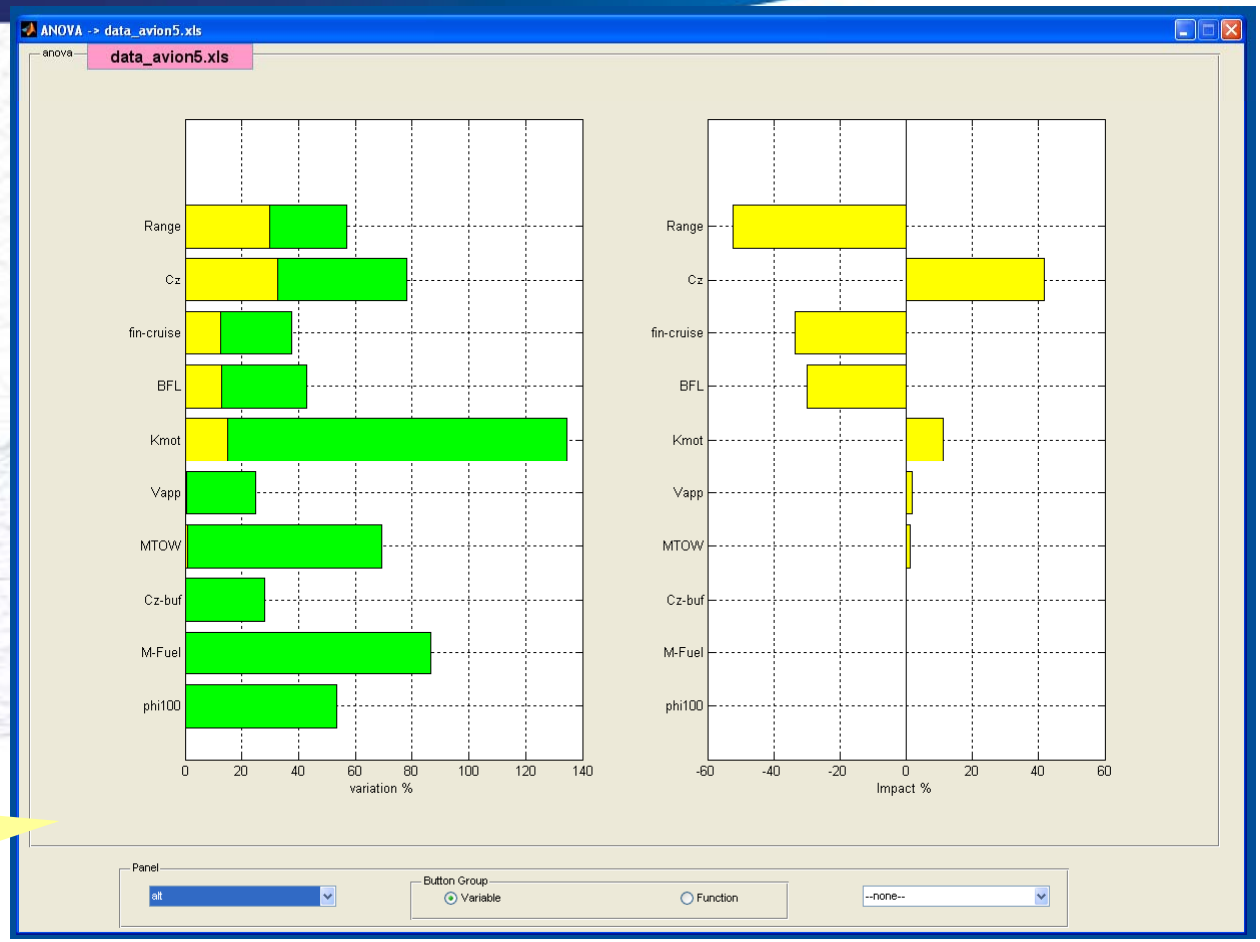




"Static" Analysis

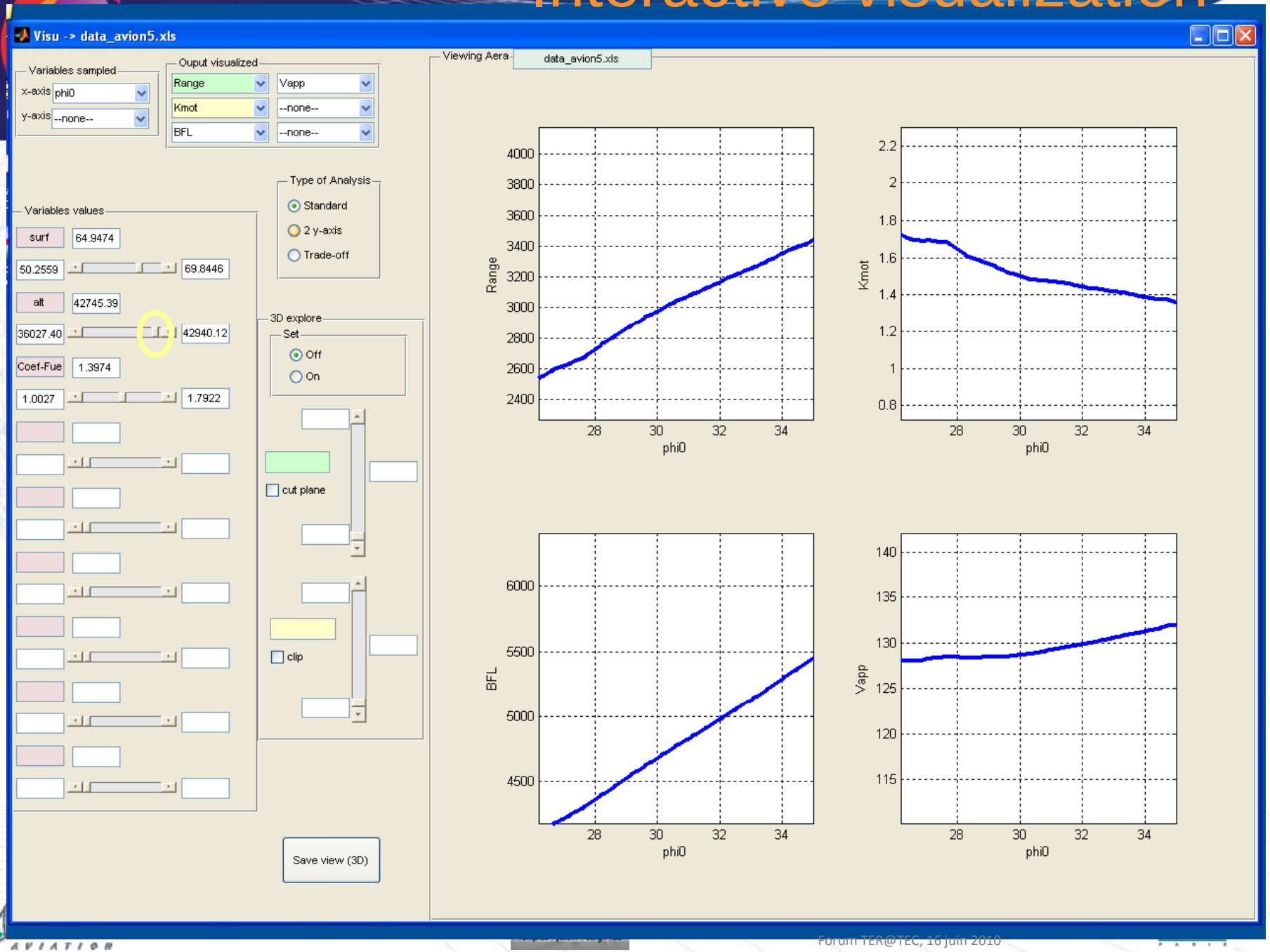
From static to dynamic

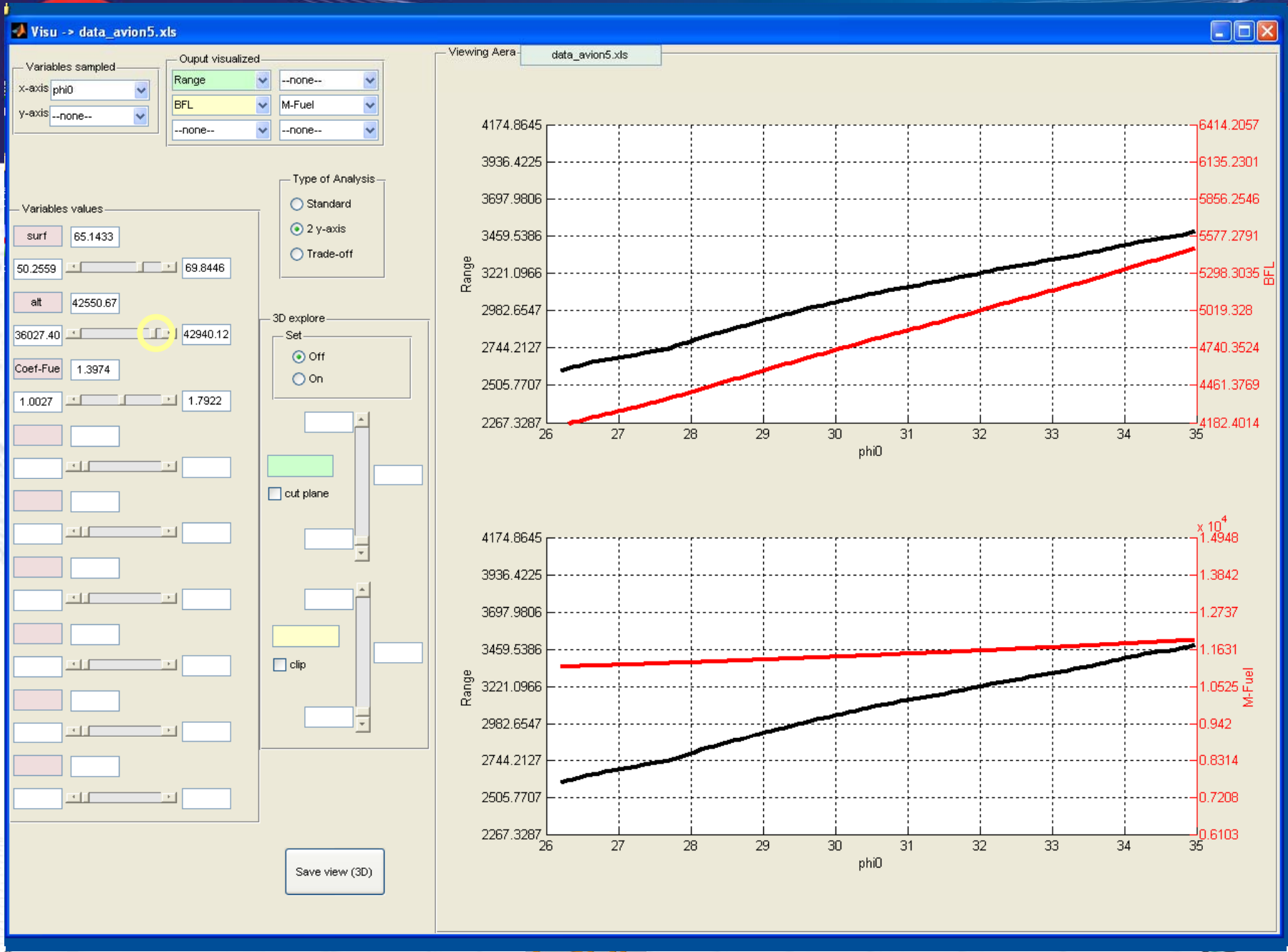




Analysis of variance

Interactive visualization

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y-axis --none--
Ouput visualized
Range --none--
BFL M-Fuel
--none--
--none--
Type of Analysis
Standard
2 y-axis
Trade-off
Variables values
surf 65.1433
50.2559 69.8446
alt 42550.67
36027.40 42940.12
Coef-Fue 1.3974
1.0027 1.7922
3D explore
Set
Off
On
cut plane
clip
Save view (3D)
Viewing Aera
data_avion5.xls
Range
BFL
phi0
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3936.4225
3697.9806
3459.5386
3221.0966
2982.6547
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Range
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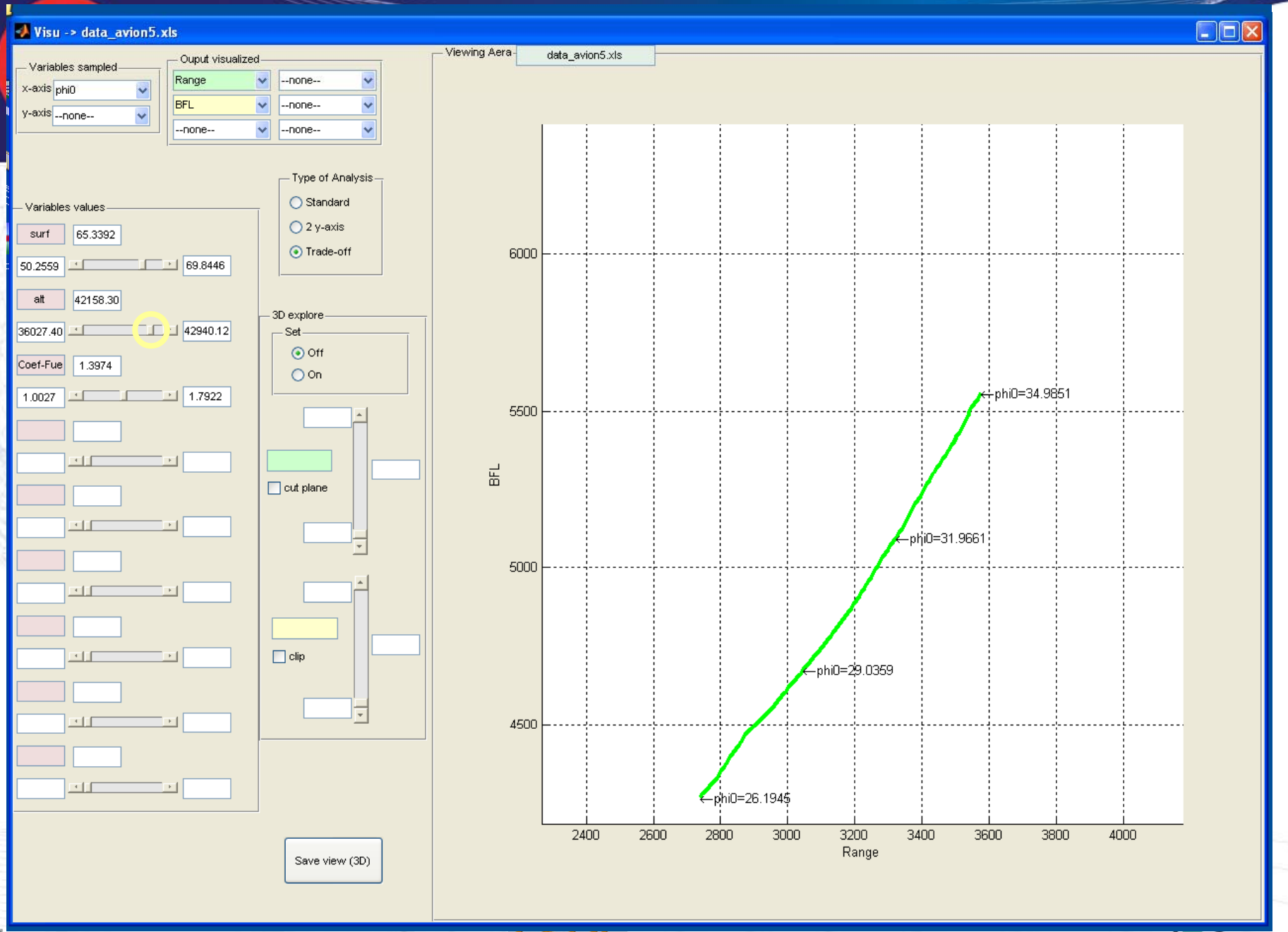
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Trade-off
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cut plane
clip
Save view (3D)
Viewing Aera
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BFL
Range
6000
5500
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4500
2400
2600
2800
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3400
3600
3800
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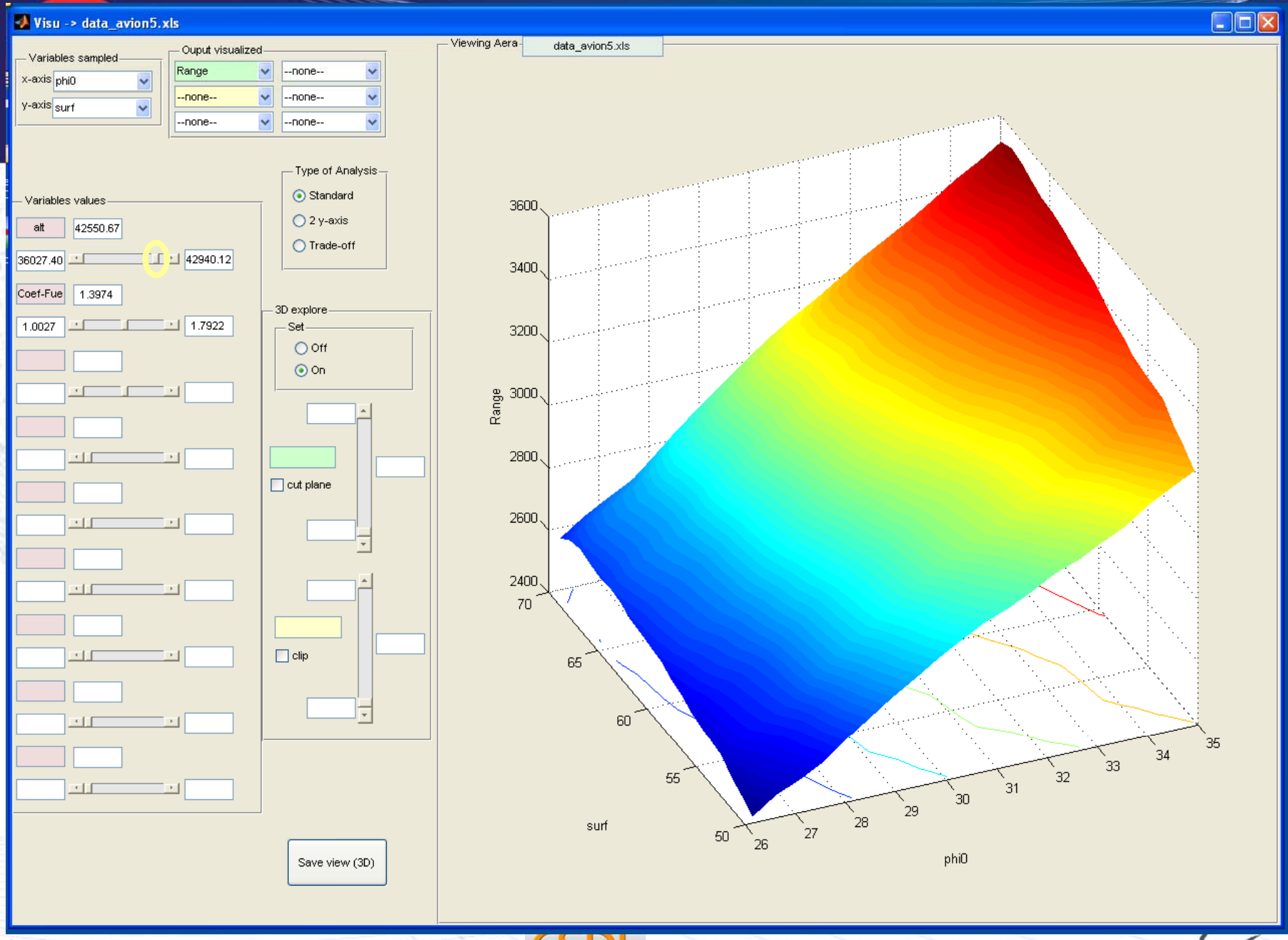
phi0=31.9661
phi0=29.0359
phi0=26.1945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Variables sampled
x-axis phi0
y-axis surf
Ouput visualized
Range
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Type of Analysis
Standard
2 y-axis
Trade-off
Variables values
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Coef-Fue
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1.7922
3D explore
Set
Off
On
cut plane
clip
Save view (3D)
Viewing Aera
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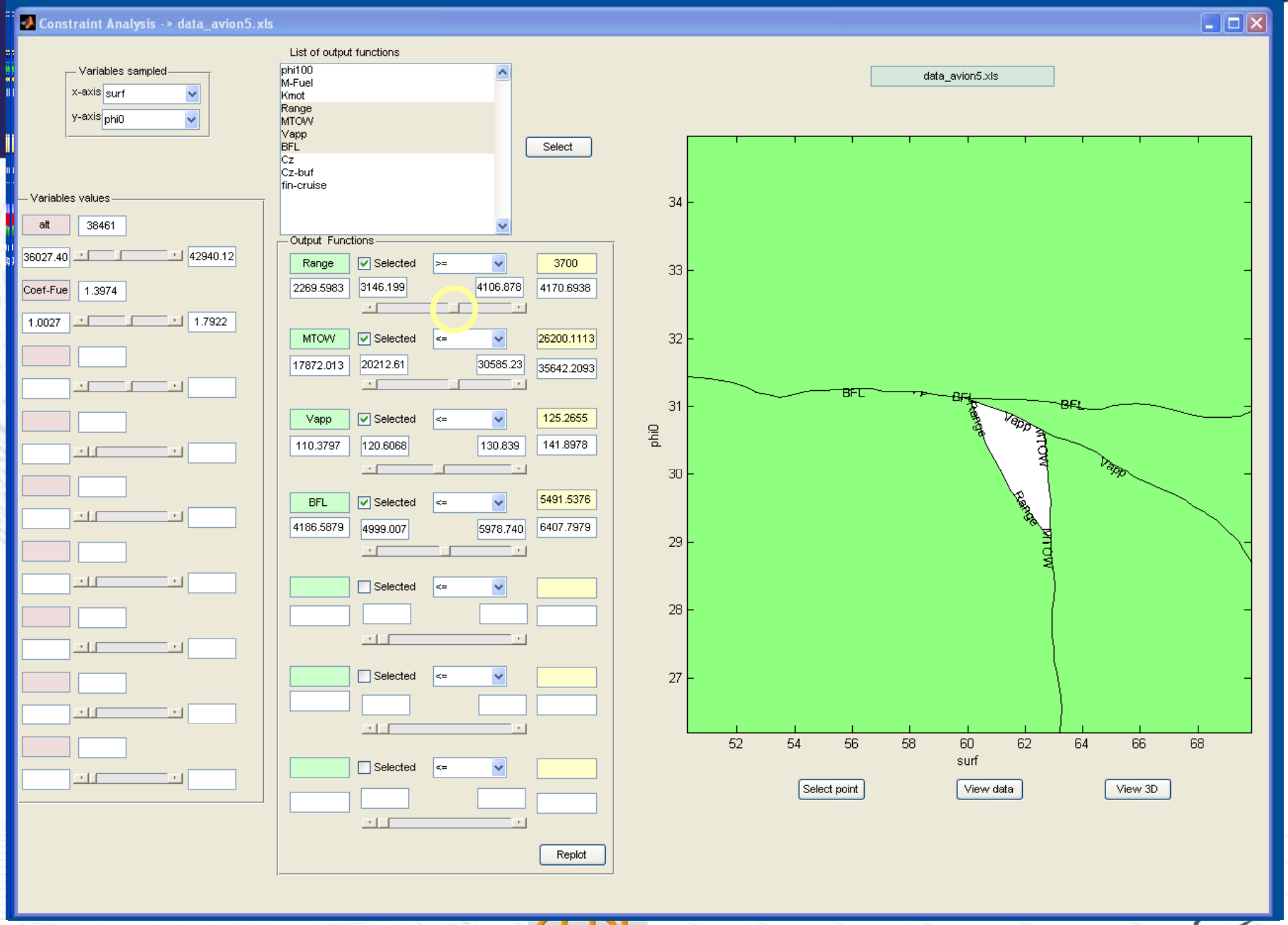
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y-axis phi0
List of output functions
phi100
M-Fuel
Kmot
Range
MTOW
Vapp
BFL
Cz
Cz-buf
fin-cruise
Select
Variables values
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36027.40 42940.12
Coef-Fue 1.3974
1.0027 1.7922
Output Functions
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MTOW Selected <= 26200.1113
17872.013 20212.61 30585.23 35642.2093
Vapp Selected <= 125.2655
110.3797 120.6068 130.839 141.8978
BFL Selected <= 5491.5376
4186.5879 4999.007 5978.740 6407.7979
Selected <=
Selected <=
Selected <=
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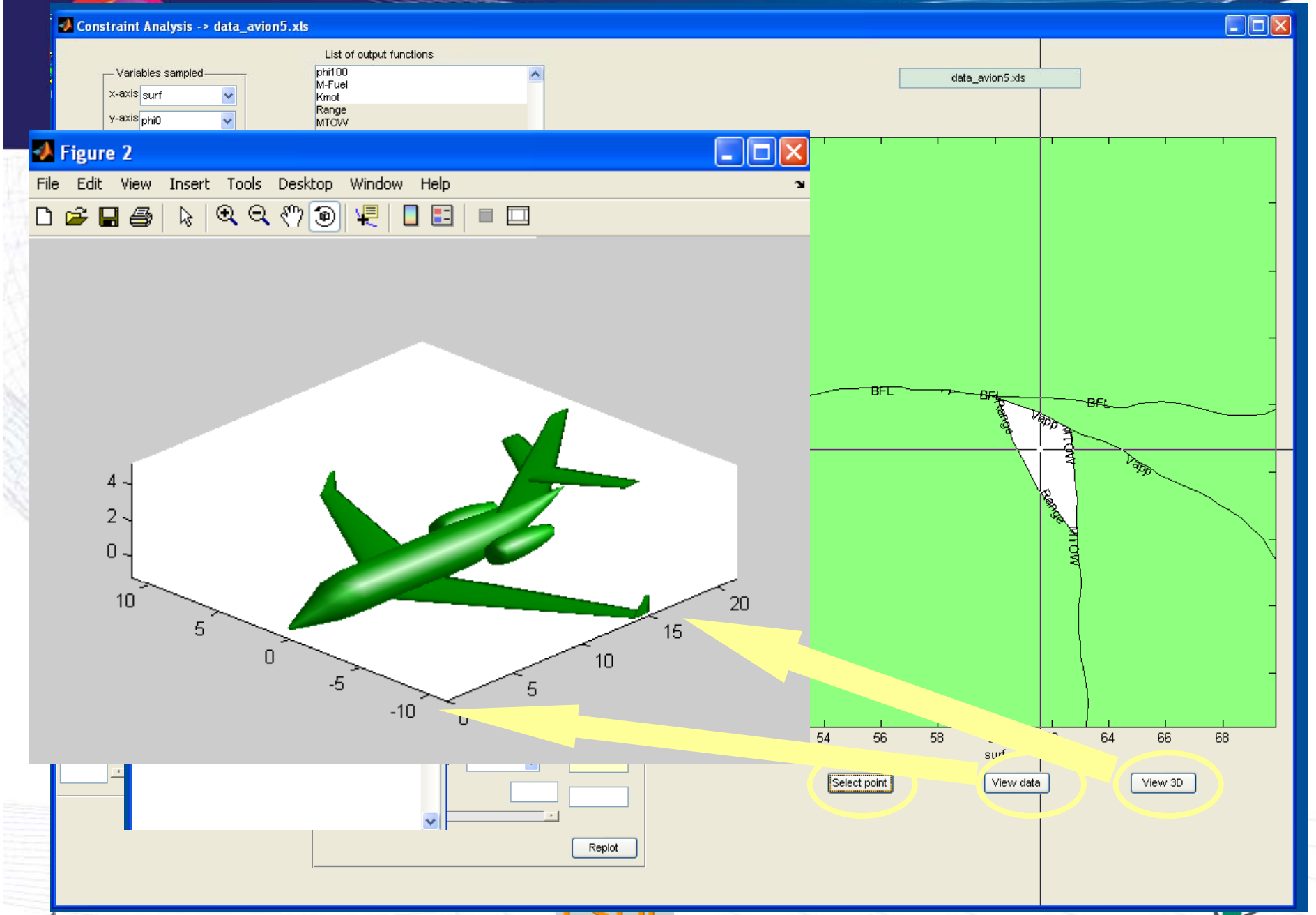
phi0
surf
BFL
Range
Vapp
MTOW
Select point
View data
View 3D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Variables sampled
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List of output functions
phi100
M-Fuel
Kmot
Range
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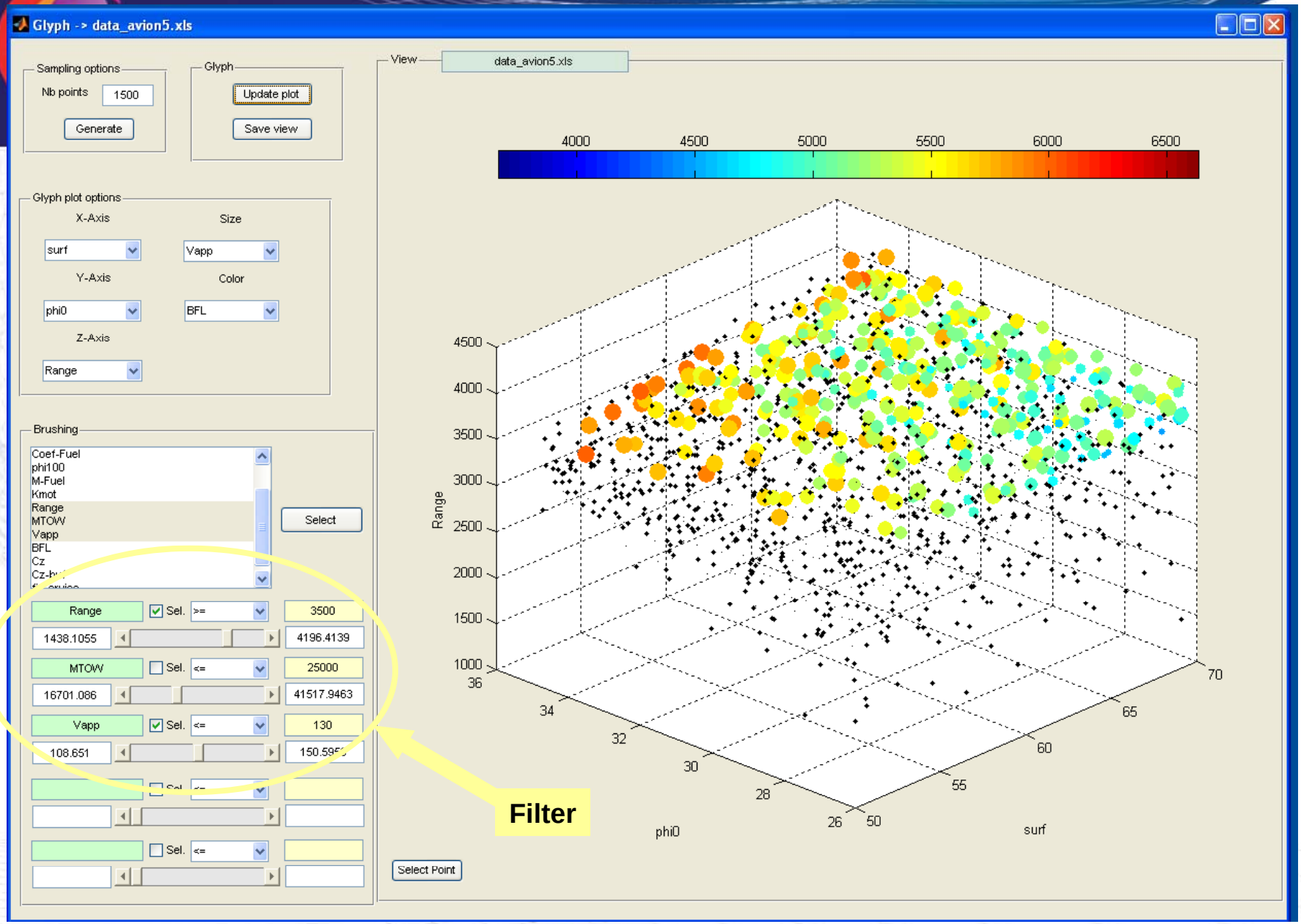
data_avion5.xls
Figure 2
File Edit View Insert Tools Desktop Window Help
BFL
Range
Vapp
MTOW
Select point
View data
View 3D
Replot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Glyph
Update plot
Save view
Glyph plot options
X-Axis
surf
Size
Vapp
Y-Axis
phi0
Color
BFL
Z-Axis
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Brushing
Coef-Fuel
phi100
M-Fuel
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Select
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4196.4139
MTOW
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<=
25000
16701.086
41517.9463
Vapp
Sel.
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data_avion5.xls
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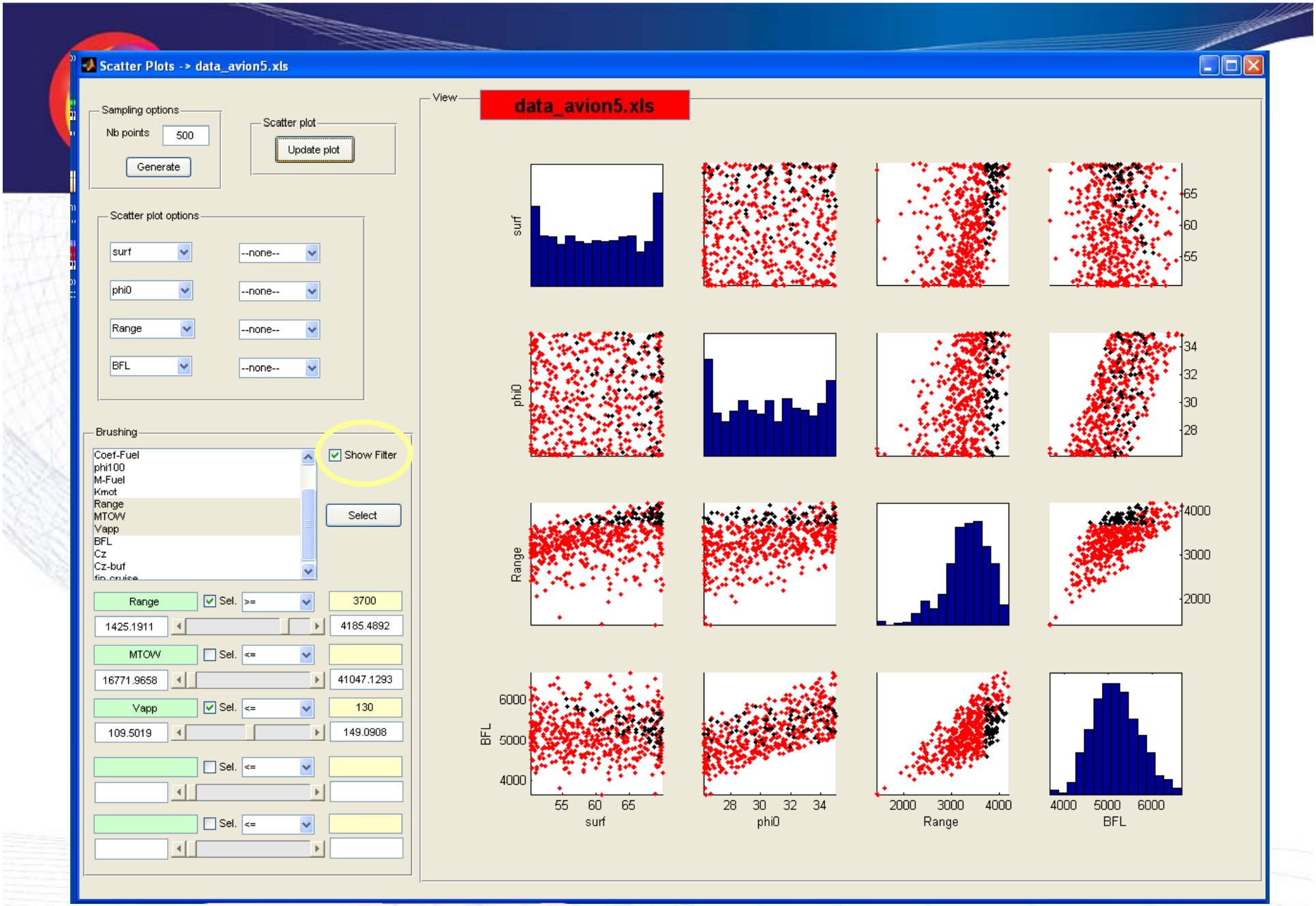
6500
Range
phi0
surf
Filter
Select Point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Nb points
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Generate
Scatter plot
Update plot
Scatter plot options
surf
phi0
Range
BFL
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Brushing
Coef-Fuel
phi100
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Range
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Cz
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Show Filter
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>=
3700
1425.1911
4185.4892
MTOW
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16771.9658
41047.1293
Vapp
130
109.5019
149.0908
View
data_avion5.xls
surf
phi0
Range
BFL

Scientific Visualization for Decision Support: **Scientific Research Vision**

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Overview

- Visualization: Wish List & Challenges

  Anastasia.Bezerianos@ecp.fr

- Online Analysis and Exploration Process

  Florian.De-Vuyst@ecp.fr

- Data Modeling and Semantics

  Rim.Djedidi@ecp.fr

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CSDL: Visualization Wish List

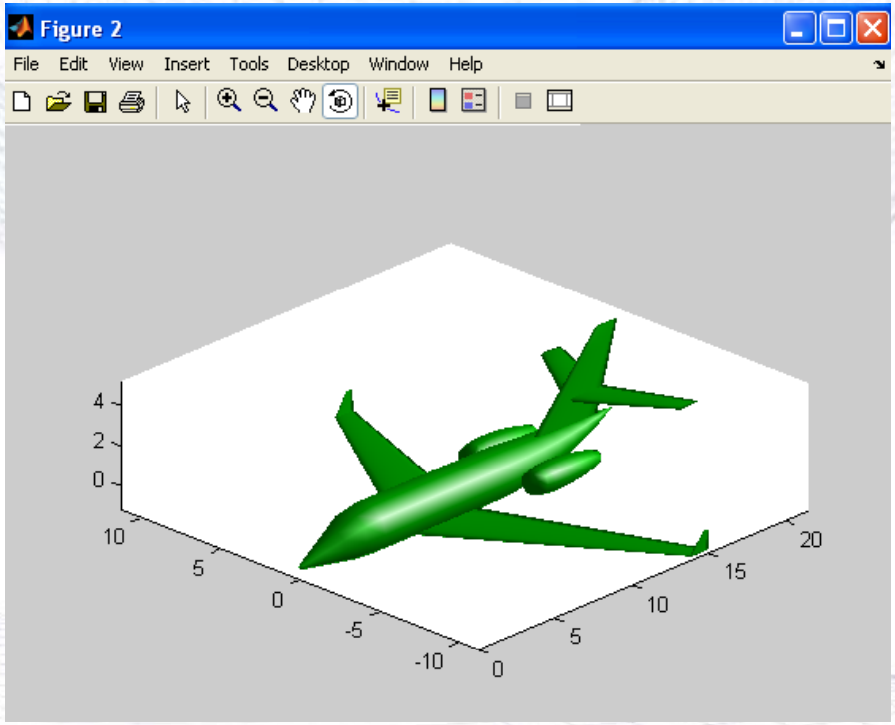
- Interactive Visualization
- Collaborative exploration
- Exploration History

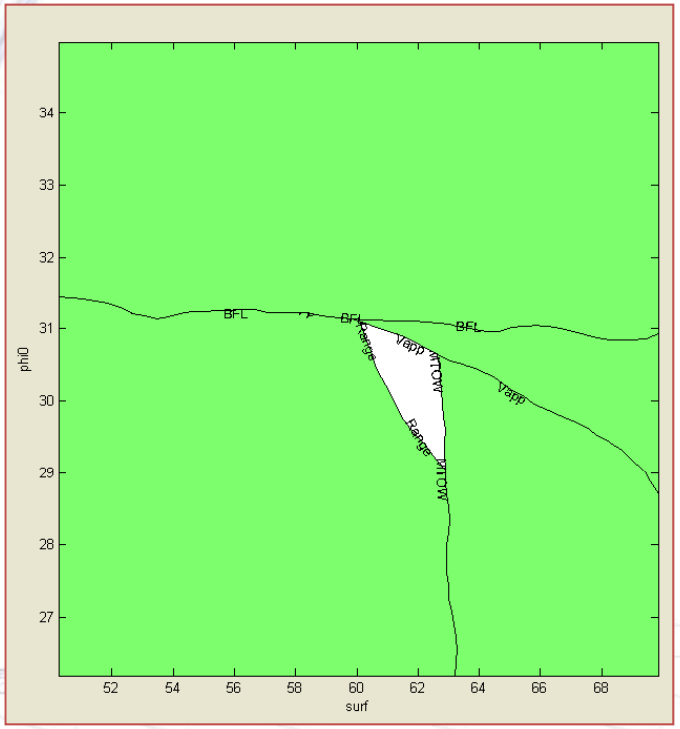
CSDL: Visualization Challenges

- Interactive Visualizations (Surrogate Models)

CSDL: Visualization Challenges

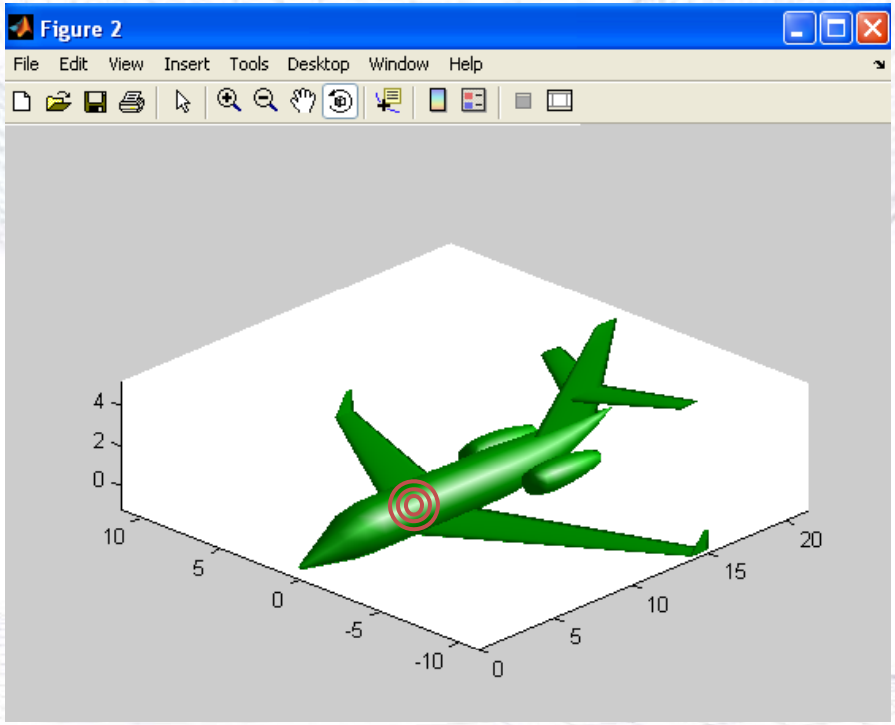
- Interactive Visualizations (Surrogate Models)
  - Interactive result exploration in different views

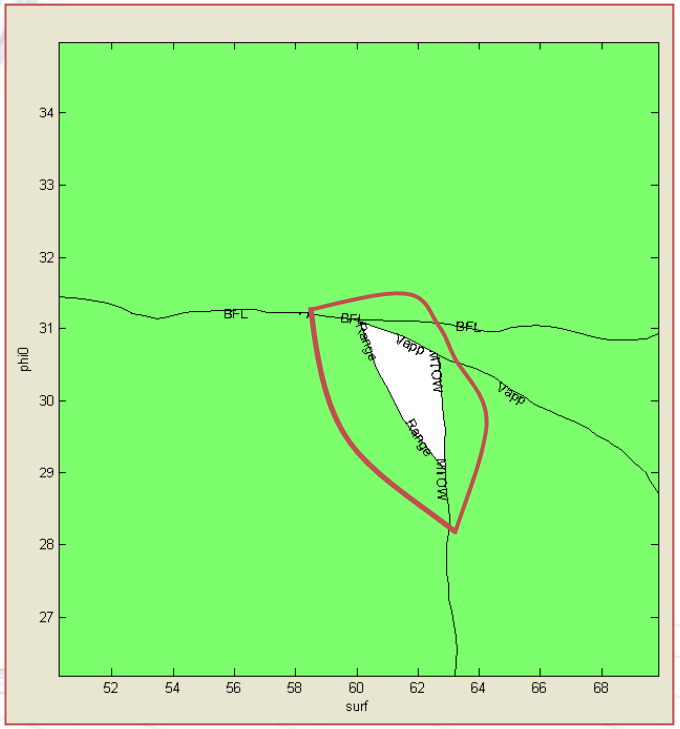




CSDL: Visualization Challenges

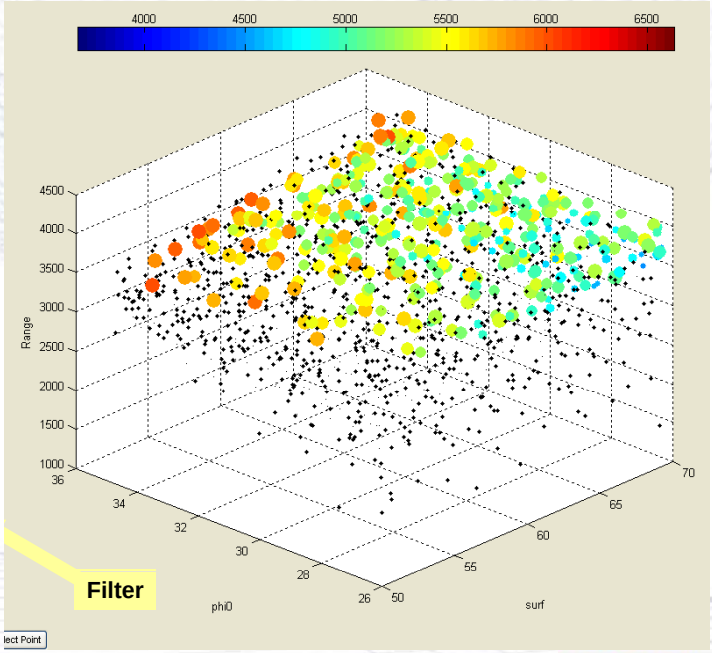
- Interactive Visualizations (Surrogate Models)
  - Interactive result exploration in different views

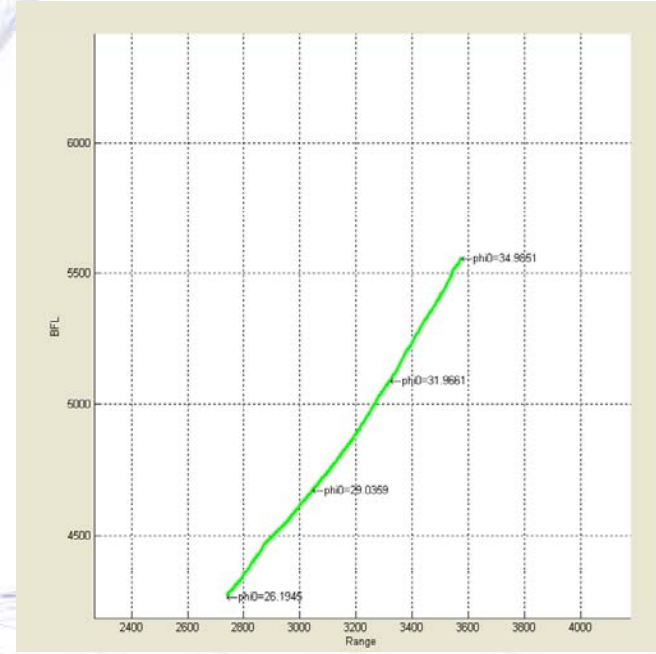




CSDL: Visualization Challenges

- Interactive Visualizations (Surrogate Models)
  - Interactive result exploration in different views
  - Interactive data re-sampling, define and present





CSDL: Visualization Challenges

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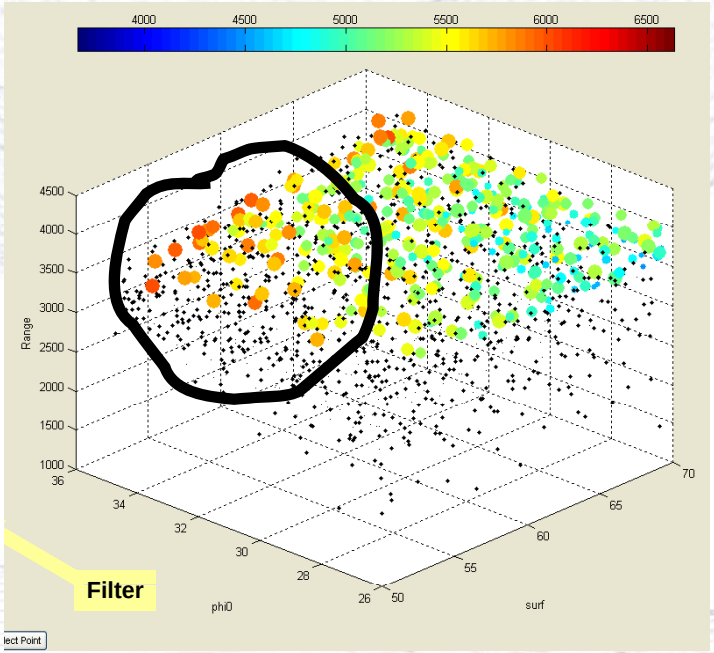

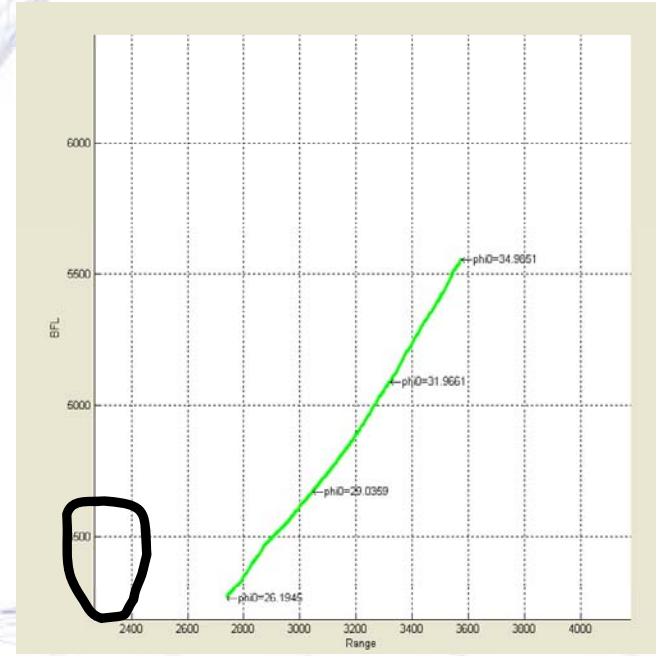

CSDL: Visualization Challenges

- Collaborative exploration

CSDL: Visualization Challenges

- Collaborative exploration
  - What interaction mechanisms to provide
  - How to treat conflicting requests

CSDL: Visualization Challenges

- Collaborative exploration
  - What interaction mechanisms to provide
  - How to treat conflicting requests
- Distributed settings, additional challenges:
  - How to handle multiple requests and delays
  - How to treat mixed infrastructure

CSDL: Visualization Challenges

- History
- Provenance and Storytelling, Latecomers

CSDL: Visualization Challenges

- History
- Provenance and Storytelling, Latecomers
  - How to go back to previous exploration steps ?
  - How to visualize paths that lead to decision ?
  - How to summarize current exploration state ?

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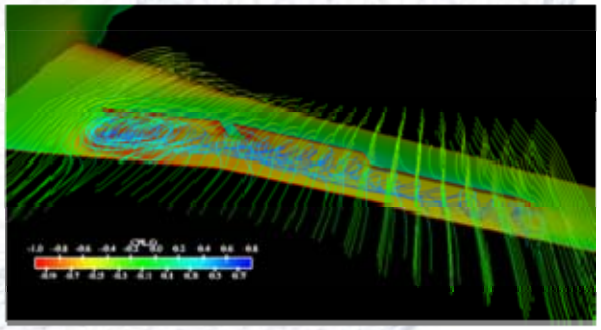
Dealing with Highly-Dimensional FE Solutions

Design parameters

$$\boldsymbol{\theta} \in \mathbb{R}^{p}$$

FE computations



© Dassault Aviation

Response/ criteria

$$\mathbf{J}(\boldsymbol{\theta})$$

$$J(\theta) = J(u^{\theta})$$

$$u^{\theta}(x) = u(\mathbf{x}, \boldsymbol{\theta})$$

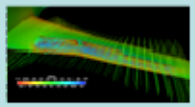
$$\text{Discrete} : U^{\theta} \in \mathbb{R}^{d},\ J^{\theta} \in \mathbb{R}^{q}$$

Typically : $1 \leq p \leq 400,\ 1 \leq q \leq 50$

$$10^{5} \leq d \leq 10^{8}$$

Challenge in Online Progressive Analysis Process

Usual standard approach (commercial software) :

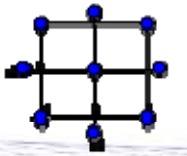
Design parameters $\theta \in \mathbb{R}^p$  Response $J(\theta)$

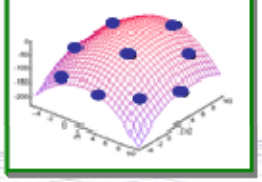
Code

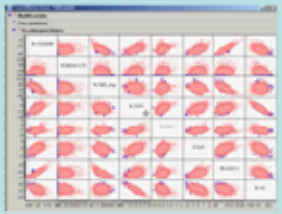
Metamodeling

Response Surface Methodology RSM

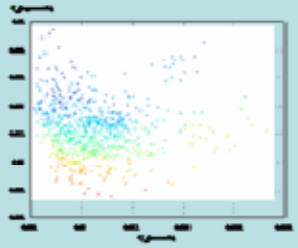
$$\tilde{J}(\theta) = \ldots$$



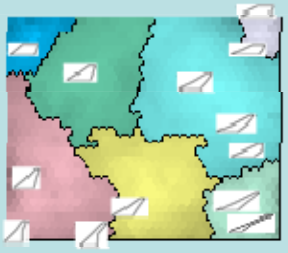




Scatterplots



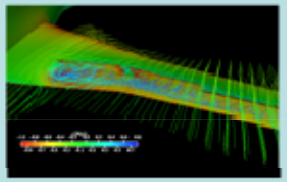
Pareto



Clustering

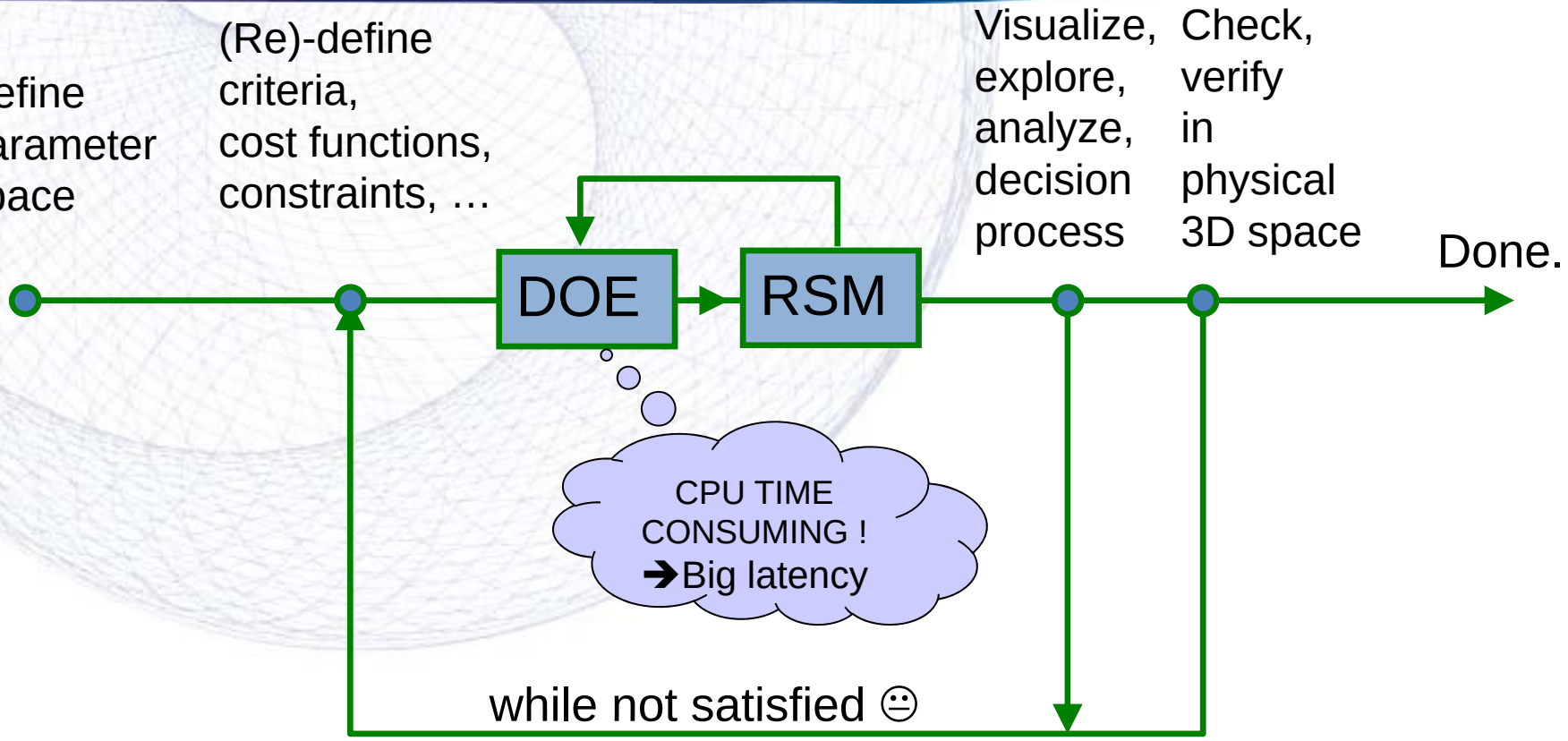
...

etc.



Check into physical space

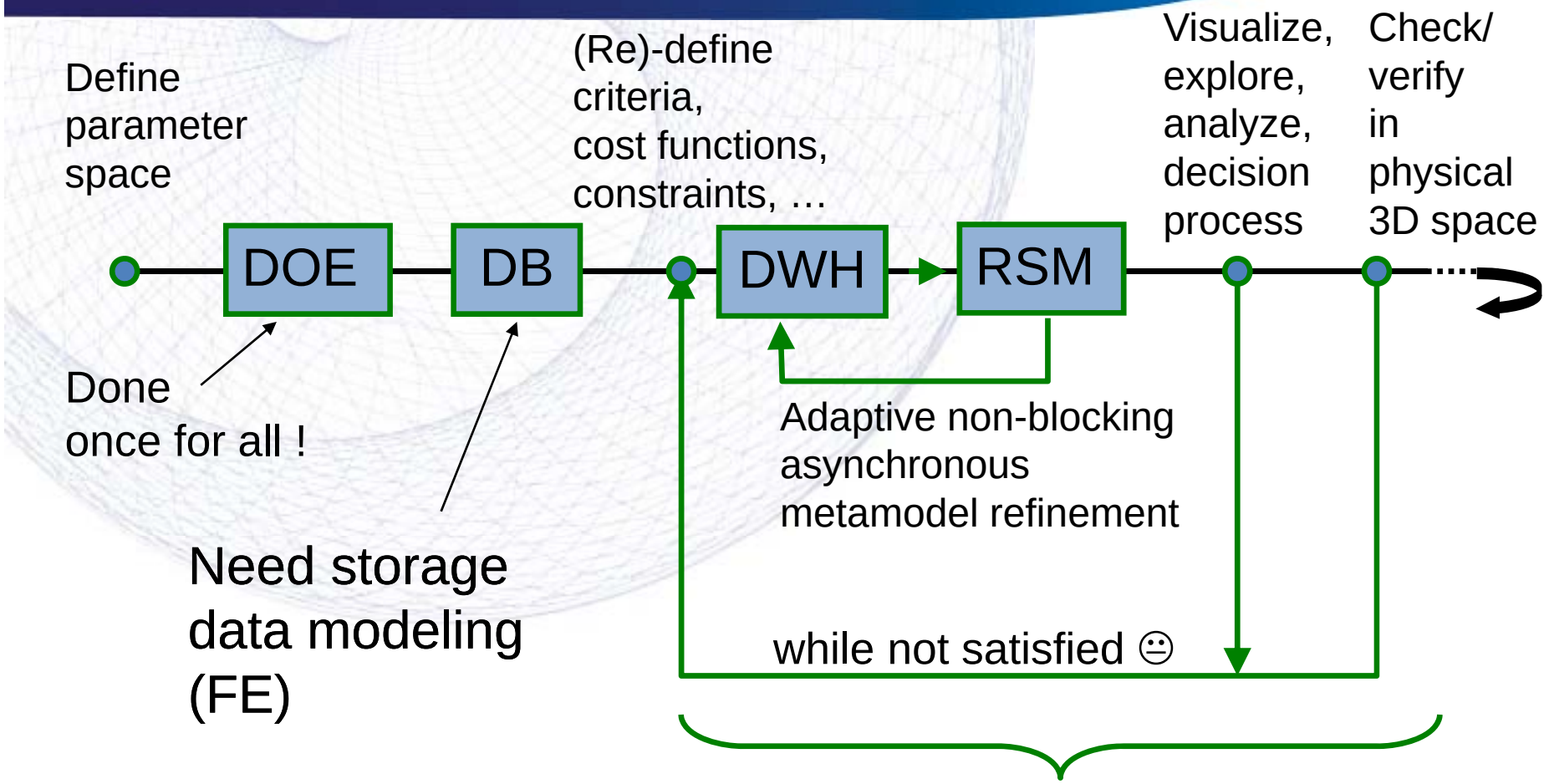
Usual Process of Exploration and Analysis



➔ Not suitable for online progressive visualization & analysis

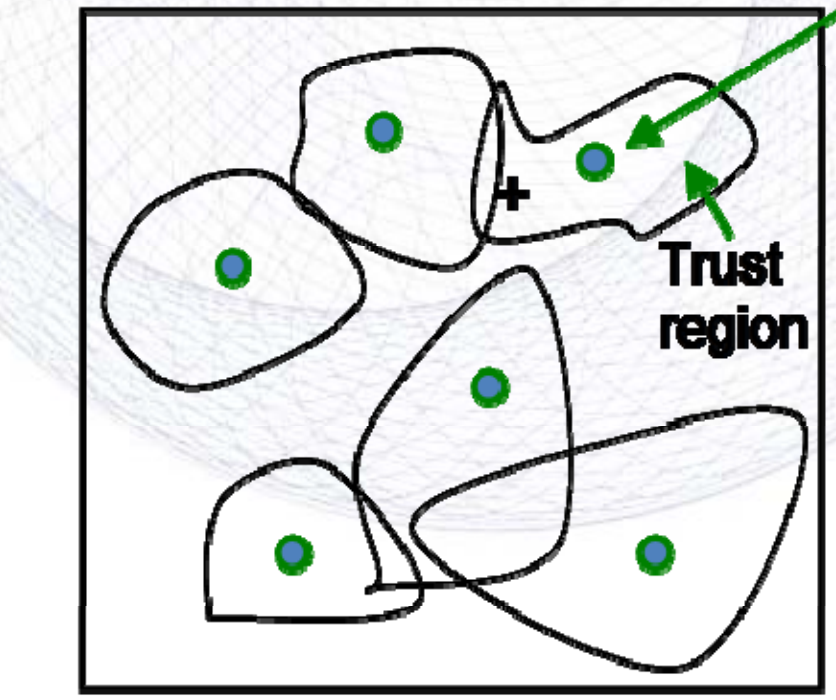
DOE : Design Of Experiment
RSM : Response Surface Methodology

A Suitable Progressive Online Visualization Process



DOE : Design Of Experiment
DB : DataBase
DWH : Data WareHouse
RSM : Response Surface Methodology

Example of POD-Based FE Reduced-Order Model
(local POD-ISAT ROM - Dung Bui PhD thesis, ECP)



Local surrogate model at point θ^i

Easy-to-compute lifting function (for BC)

Shift

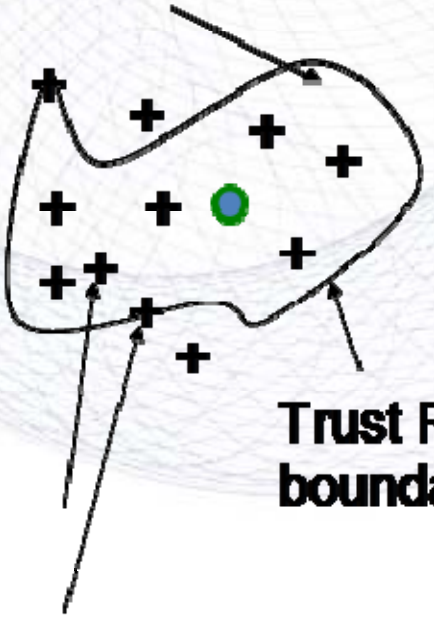
$$\tilde{u}^{\theta}_{(i)}(x) = u^{lift}(\theta)(x) + (u^i - u^{lift}(\theta^i))(x) + \sum_{k=1}^{K} a_k(\theta)\, \Psi^k_{(i)}(x)$$

Local POD modes

POD coefficients (need a learning step)

Local POD-ISAT Surrogate Record

$$\tilde{R}(\tilde{u}^{\theta}) \leq \epsilon_{threshold}$$



Residual estimates
at different sampling points

Database content :

- The "center" point θ^i
- The FE solution $u^i = u(\theta^i)$
- A local surrogate form $\tilde{u}_{(i)}(\theta)$
- Some POD coefs $a_k(\theta)$ computed

by minimization of the residual

- A Trust region model $\tilde{R}(\tilde{u}^{\theta})$

computed from a SRM of the residual

Integration into the Progressive Collaborative Online Visualization Environment

MAIN TASK

- Need to “explore” a new design area
- Is there any accurate surrogate ?

YES

Good ! Keep going..

- Visualize …

NO

Oops ! Create new local surrogate

NEW THREAD
FE COMPUTATION

- Inform user and collaborators

Alert ! Ongoing modeling…

PARALLEL THREAD

Improve residuals and trust regions accuracy of existing local surrogate models (if necessary)

Time line

ONLINE

ENRICH

REFINE

Overview

- Visualization: Wish List & Challenges

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- Online Analysis and Exploration Process

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- Data Modeling and Semantics

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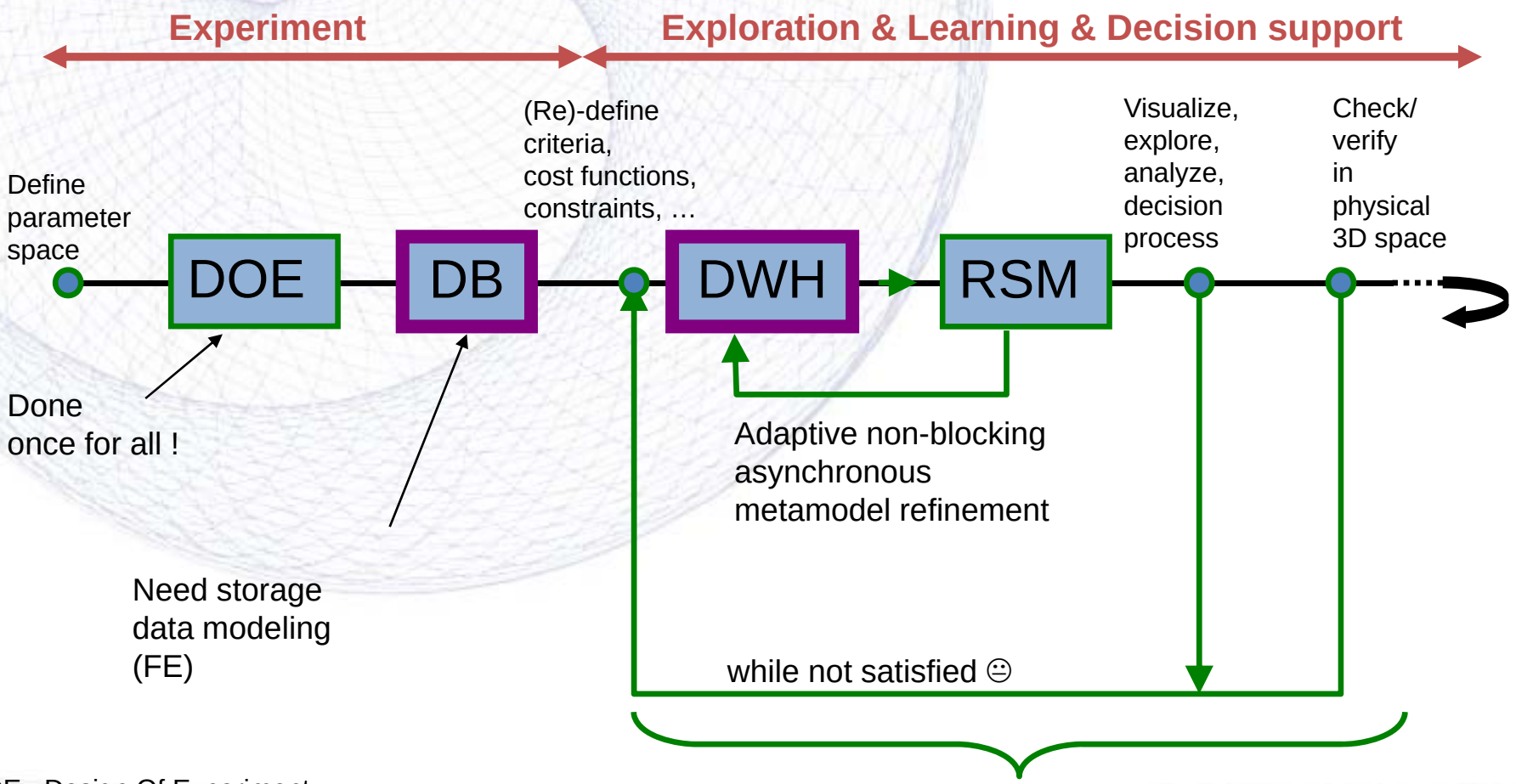
Data Modeling Requirements for online visualization process



Collaborative online visualization environment

DOE : Design Of Experiment
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Scientific Data Modeling

Experiment Level

- Raw Data Set
  - Design Parameters
  - FE solutions of DOE Sampling points

Exploration & Learning Level

- Criteria, Cost Functions, Constraints, …
- Surrogate models

  - Example POD Reduced-order model
    - POD Modes, POD coefficients, Trust Region
- Design preferences
- Multiple customizations

Large Data Storage Solution

2 Systems to coexist !

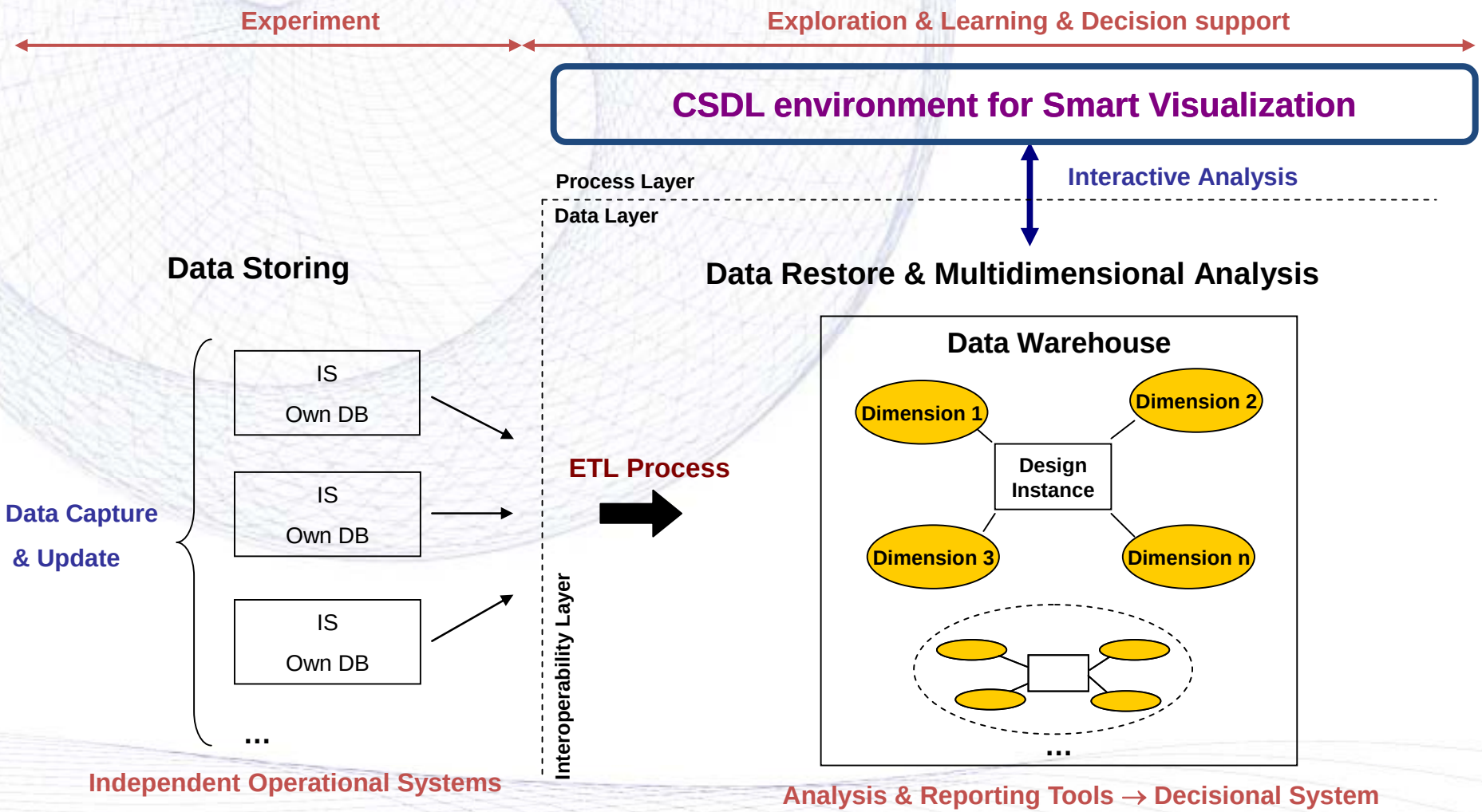
1. Operational system for data storing

   ➔ **Learning Database (DB)**

2. Data restore & multidimensional analysis system

   ➔ **Data Warehouse (DWH)**

Preliminary Architecture



IS : Information System
ETL : Extracting, Transforming, Loading

Large Data Storage Solution

2 Systems to coexist !

1. Operational system for data storing

   ➔ **Learning Database (DB)**

2. Data restore & multidimensional analysis system

   ➔ **Data Warehouse (DWH)**

   - Combining several multidimensional models (data marts)
     - One multidimensional model for each analysis axis
   - Coherent set of dimensions and facts
     - Temporal, spatial or thematic dimensions
     - Facts modeling design instances (criteria & aggregated functions)

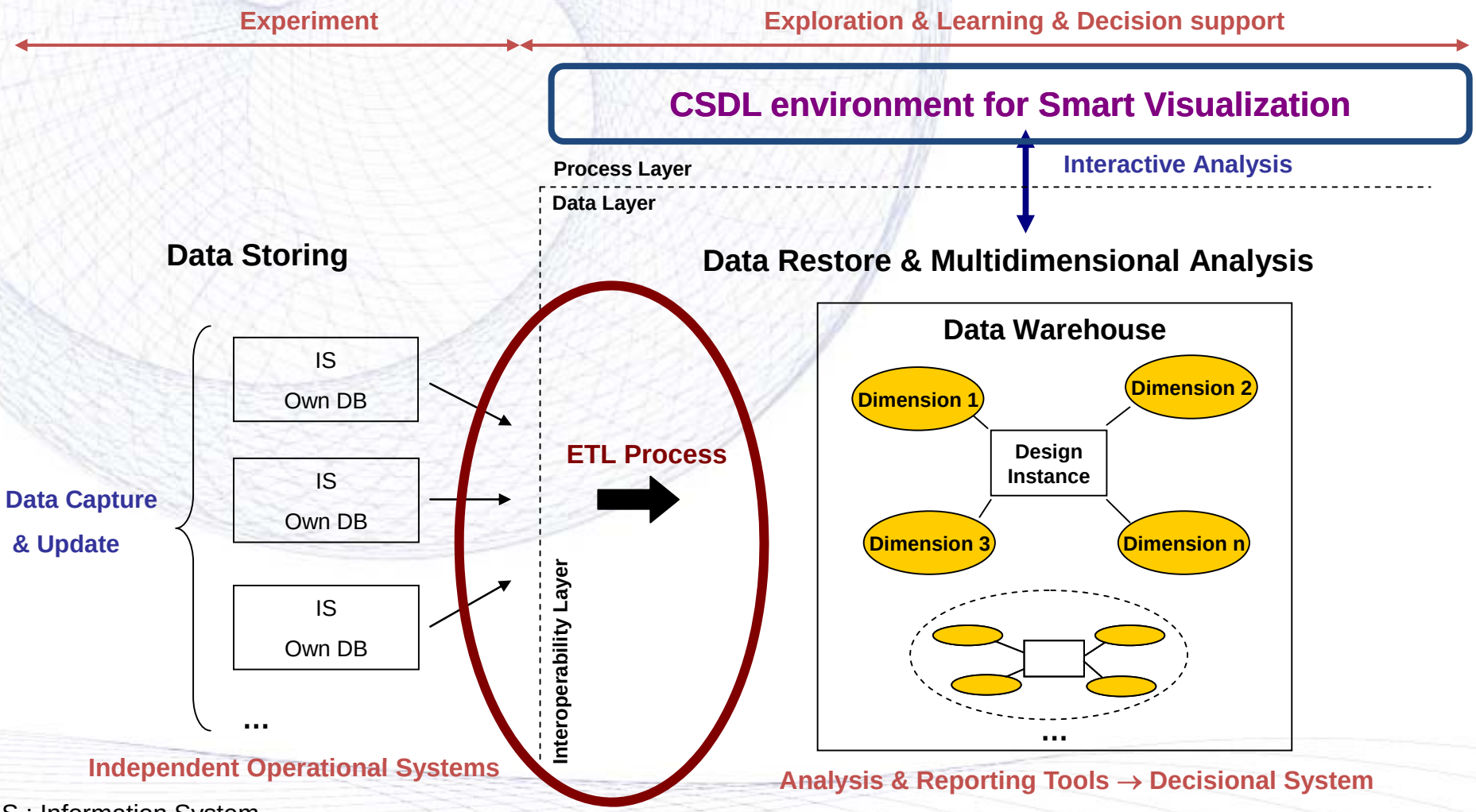
Semantic Support

Common and shared vocabulary

- Structuring and Integrating data extracted from heterogeneous data sources

  ➔ **Interoperability Layer**

Preliminary Architecture



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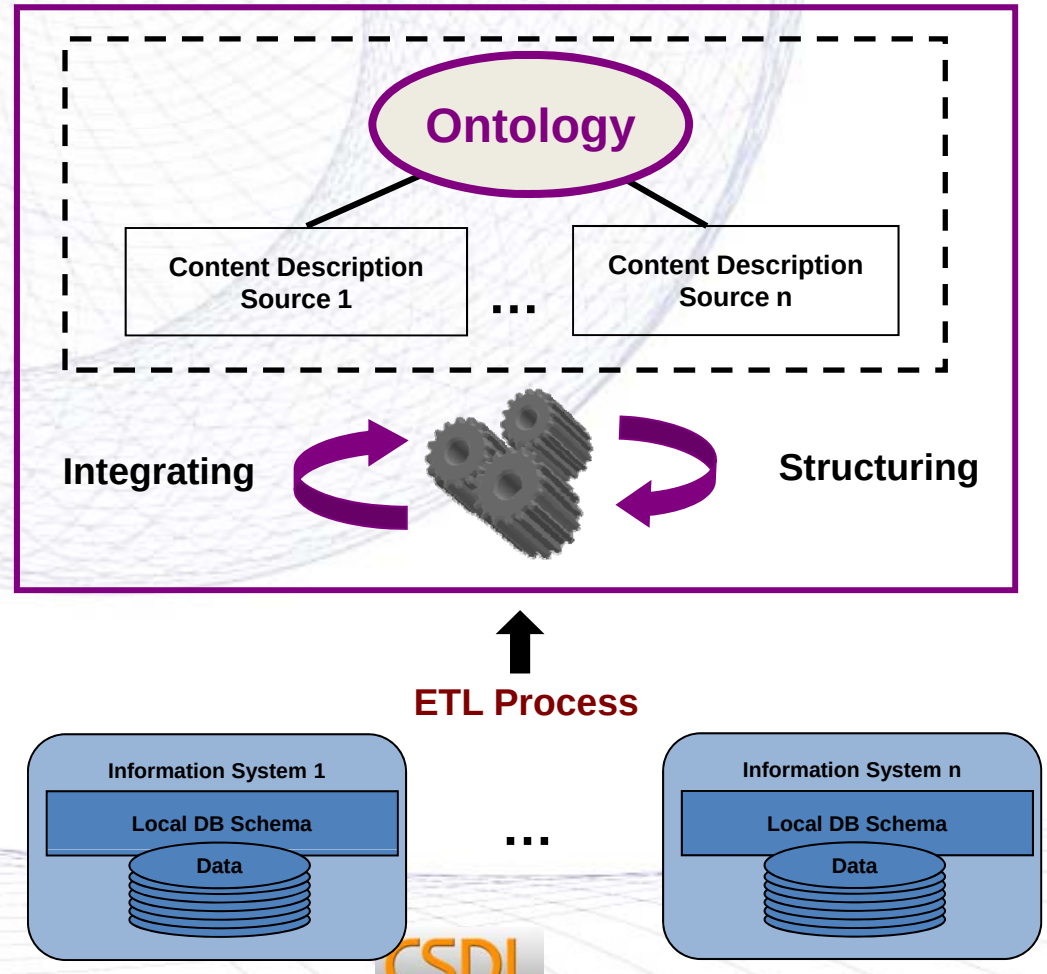
Semantic Referent for Data Integration

Interoperability Layer



Semantic Support

Common and shared vocabulary

- Structuring and Integrating data extracted from heterogeneous data sources

- Handling Heterogeneous Models
  - ➔ **Querying heterogeneous models**
  - ➔ **Model Comparison – Transformation – Integration**
  - ➔ **Model Reuse – Composition**
  - ➔ **Model Annotation and traceability**

Conclusion

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Conclusion

- Major challenges:
  - Intuitive data representation and interaction in collaborative environments
  - Visualization of uncertainties
- Technologies which need further developments:
  - Surrogates models
  - Model management
  - Exploration techniques (e.g M-O Optimization)
  - MCDM tools